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The Dietary Deficiency of Cereal Foods with Reference to Their Content in "Antineuritic Vitamine."

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Introduction.—Recent experimental work has called attention to the importance of certain so-called accessory foods or vitamines in their relation to proper nutrition. The work of Stepp, Hopkins, Funk, Osborne and Mendel, McCollum and Davis, and others, has demonstrated that a diet is not complete and does not permit of adequate nutrition unless it contains sufficient amounts of two accessory substances. One of these substances is essential in the prevention and cure of beriberi in man or polyneuritis of fowls, and has been termed the "antineuritic vitamine" or the water soluble B. The other substance occurs in certain foods rich in fat (butter, etc.), and has been designated as fat soluble A by McCollum and his coworkers.

This paper deals with the occurrence of the antineuritic vitamine in foods derived from wheat or corn. Researches of a similar nature have been made by other investigators, and the fact has been thoroughly established that all natural cereals contain an abundance of antineuritic vitamine, an amount considerably in excess of that needed when these cereals form the exclusive diet of animals.

Valuable as these investigations are in regard to the feeding of animals and the purely scientific aspects of nutrition, the previous investigators have not sufficiently taken into consideration the fact that cereals in the form of the entire grain are only rarely consumed by man. The bulk of the cereal component of the diet of our people is represented by wheat or corn bread. Wheat and corn bread are largely prepared from flour or corn meal which represents only part of the wheat or corn kernel. The commonly used "patent" flour, for instance, contains only about 70 per cent of the wheat from which it is milled. The question, therefore, arises as to whether or not bread made from "white" flour or "highly milled" corn meal includes all the essential food elements contained in the intact grain.

The present paper reports a continuation of work done by others with respect to the antineuritic vitamine of corn and wheat products used in nutrition. In a succeeding paper certain other dietary attributes of these foods will be considered in their relation to growth.

Previous work.—Experimental and clinical work on the etiology of beriberi has demonstrated the fact that polished rice may give rise to beriberi in man and to polyneuritis in fowls when used to the more or less complete exclusion of other foods. It has, furthermore, been shown that substitution of unpolished rice for polished rice prevents the occurrence of beriberi and polyneuritis. Moreover, it has been found that the rice polishings contained the antineuritic vitamine, the substance which is responsible for the prevention and cure of beriberi. Thus unquestionable proof was furnished that the "highly milled" (polished or white) rice has been deprived of an essential dietary element resident in the peripheral layers of the intact grain.

Because of these results with rice, the attention of investigators interested in this field was soon attracted to wheat bread. Thus Holst (1907), in experimental studies relating to ship beriberi and scurvy, carried out on pigeons a few experiments with rye and wheat bread, baked with yeast or baking powder. The pigeons on wheat bread developed symptoms and nerve degeneration characteristic of polyneuritis. The addition of yeast to the wheat flour seemed to delay the onset of the symptoms, but did not prevent a gradual loss of body weight (30 per cent). The pigeons fed on rye bread or whole wheat bread, however, lived for four months without showing any abnormalities. Holst does not mention the kind of wheat flour used in his experiments beyond stating that it was "the flour ordinarily used by Norwegian sailors in tropical waters."

Simpson and Edie (1911) describe a few additional experiments on the feeding of "whole wheat" bread and "white" bread to pigeons. On the "whole wheat" bread the birds continued active and well, and two pigeons paired and successfully hatched the two eggs. The pigeons fed "white" bread died after an average of 29 days with an average loss of weight of 26 per cent. Typical paralytic symptoms were observed in these animals and marked degenerative changes were found in their peripheral nerves. Several of these birds were treated when extremely weak with either yeast or beans. Great improvement in the condition of the birds followed this treatment.

The reports of Little (1912 and 1914) concerning his five years' experience with epidemics of beriberi in Newfoundland are very important, as they show that in this locality beriberi was due to a diet limited to "white" bread made from highly milled flour, molasses, a small quantity of fish, and tea. This author furthermore presents evidence to the effect that the substitution of "whole wheat" bread for the "white" bread was followed by a disappearance of the disease, in spite of the fact that the other dietary and hygienic conditions were apparently left unchanged.

At Little's suggestion, Ohler (1914) carried out a number of experiments with chickens, in order to furnish experimental proof for the contention that a more or less exclusive diet of "white" bread was the chief cause of the occurrence of beriberi in Newfoundland. Fourteen chickens fed on "white" bread, made from "highly milled" flour with or without the addition of yeast, died within 28 to 40 days. Before death the birds exhibited symptoms of polyneuritis, and histological examination of the peripheral nerves revealed considerable degeneration. Five fowls fed on "whole-wheat" bread and two on whole wheat lived in perfect health for 75 days, when the experiment was discontinued.

Similar experiments were carried out by Wellmann and Bass (1913) and by Voegtlin, Sullivan, and Myers (1916).

Nature of the present experiments.—Pigeons and chickens were used in these experiments for the reason that they are better adapted for feeding experiments with cereals than other animals. Only full-grown birds were used. The symptoms resulting from a deficiency of the diet in antineuritic vitamine are easily recognized in fowls, and curative experiments yield striking results. The observations made on birds were confirmed in experiments on dogs, hogs, and a large number of white mice (these results will be published elsewhere). As a rule, the birds were given as much of the various corn and wheat foods as they cared to eat. In a few experiments, by mistake they did not receive sufficient food, a fact which caused them to lose in body weight (experiments Nos. 18, 20, and 25). The appearance of polyneuritic symptoms was regarded as indicating that the particular food in question was deficient in antineuritic vitamine. The polyneuritic symptoms were always preceded by a gradual loss in body weight. The peripheral nerves of a large number of the birds were examined histologically at the end of the period of observation, and always confirmed the conclusions drawn from clinical observations. Birds exhibiting polyneuritic symptoms during life always showed marked myelin degeneration of their peripheral nerves.

The corn and wheat products were obtained in the open market and came from various modern roller mills, old-fashioned buhr mills and various bakeries.

As a rule, the total phosphorus pentoxide content of the dried products was determined, as it had been shown by other investigators that the phosphorus and vitamine contents of rice of various degrees of milling run roughly parallel.

In order definitely to prove that the symptoms observed in the animals kept on deficient foods were due to a deficient supply of antineuritic vitamine, some of the pigeons were treated after the onset of the disease with various vitamine preparations (Funk's vitamine fraction) obtained from brewer's yeast, ox liver, or rice polishings. Further evidence was obtained from protective experiments in which there was added to the deficient food a small quantity of a vitamine preparation. This material was prepared according to the method described by Seidell (1914). The so-called activated Lloyd's reagent consists of fuller's earth (Lloyd's reagent), which has been treated with autolyzed yeast filtrate. It contains an average of 2.3 per cent of total nitrogen, which is derived from the basic substances of autolyzed yeast filtrate.

As it was confirmed in the course of the investigation that white bread was deficient in antineuritic vitamine, a few experiments were made to determine the effect of adding an extract of "whole-wheat" bread to the diet of "white" bread. This extract was prepared as follows: Two hundred and eighty grams of "whole-wheat" bread were extracted twice at room temperature with one liter of 50 per cent alcohol containing 25 cubic centimeters of concentrated hydrochloric acid. The filtered extract was concentrated in vacuo to a small volume, so that 1 cubic centimeter of the extract corresponded to 1 gram of fresh "whole-wheat" bread. The extract was free from fat and contained 11.5 per cent of solids.

The animals were kept in wire cages, tap water being supplied daily and grit from time to time.

The bread was fed in the form in which it was received from the dealer. Water was added to the flour, which was made into cakes. The cakes were dried at 45° C. and broken up into pieces of suitable size.

Throughout this paper the words "highly milled" are meant to indicate that the product was milled in a manner to eliminate most of the superficial layers and the germ of the grain. "White" bread is the ordinary wheat bread made from "highly milled" flour. "Patent" flour is the word applied by the milling industry to a flour which is of very fine texture and almost white in appearance. It contains practically no bran or germ. By "old-fashioned" Graham flour is meant a wheat flour which is obtained by grinding wheat in buhrstone mills with the omission of bolting. "Whole-wheat" flour is a designation of a flour which contains the whole-wheat berry, with the exception of part of the bran. "First-clear" flour resembles "patent" flour but contains a small amount of the peripheral portions of the grain. Similar designations have been used for the corn foods. The following tables and charts will illustrate the main results obtained in this investigation.

EXPERIMENT 1.—*"Old-fashioned" Graham flour milled in the presence of one of authors (V) in an old-fashioned buhr mill in Spartanburg, S. C.*

[Appearance: Typical Graham flour, containing considerable bran and germ. P_2O_5 content: 0.866 per cent.]

(Beginning with the twenty-fifth day of the experiment, a similar Graham flour was substituted for the above product.)

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
308	No symptoms	118	+ 2	Sciatic normal.
309	.....do	118	+ 9	Do.
312	.....do	123	+21	Sciatic not examined.
313	.....do	96	+12	Do.
311	.....do	113	+13	Do.

Remarks.—On the 25th day of the experiment the food was changed to another old-fashioned Graham flour (P_2O_5=0.82 per cent), obtained from another buhrstone mill in Spartanburg, S. C. This mill had been in operation for at least 50 years. Slight changes were made in its power plant, substituting turbines for the "water wheels." The process of milling, however, was still the same as at the time of the opening of the mill.

Both of these flours contained sufficient antineuritic vitamine to prevent polyneuritic symptoms and loss of body weight. Their P_2O_5 content is almost as high as that of whole wheat.

EXPERIMENT 2.—*"Whole wheat flour" milled in St. Louis, Mo.*

[Appearance: Grayish white. P_2O_5 content: 0.61 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
332	No symptoms	90	+21	Sciatic normal.
333	.....do	90	−28	Do.
336	.....do	91	−33	Do.
337	.....do	103	−22	Do.
335	.....do	96	−36	Do.

Remarks.—Pigeon 337 died apparently from accidental causes, as the necropsy revealed a piece of copper wire, which had perforated the craw and prevented the animal from eating. The other pigeons appeared in perfect health until a few days previous to end of period of observation. No definite paralytic symptoms were observed in any of these birds and the histological examination of the sciatic nerves also yielded negative results.

This flour contained sufficient antineuritic vitamine to prevent polyneuritic symptoms and fatty degeneration of the peripheral nerves. Its P_2O_5 content is somewhat lower than that of whole wheat.

EXPERIMENT 3.—*Wheat flour obtained from old-fashioned buhr mill, Roebuck, S. C.*

[Appearance: White, with yellowish tinge; contains particles of bran. P_2O_5 content: 0.265 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
315	No definite symptoms	Died after 109 days	−36	No treatment.
317	Twenty-second day	Died after 27 days	−15	Do.
318	No definite symptoms	Killed after 158 days	−28	Do.
319	No symptoms	.....do	+ 4	Do.

Remarks.—Sciatic nerves of pigeons 315 and 319 did not reveal any degenerative changes and were to all appearances normal. Sciatic nerve of pigeon 318 revealed a slight degeneration.

This flour represents a fairly "highly milled" product. It was bolted through a fine silk cloth, which eliminated a considerable part of the germ and bran. In physical appearance this flour is not as refined as "patent" flour. It obviously contains more antineuritic vitamine than "patent" flour but not as much as "whole-wheat" flour. The P_2O_5 content is also low.

EXPERIMENT 3a.—*Wheat flour obtained from old-fashioned buhr mill, Spartanburg, S. C.*

Appearance: White with yellowish tinge; contains small particles of bran. P_2O_5 content: 0.27 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
338	Remained well	Killed after 118 days	−13	Not treated.
339	No symptoms	Died after 102 days	−12	Do.
340	Remained well	Killed after 118 days	− 6	Do.
341	.....do	.....do	− 5	Do.
343	Thirtieth day, doubtful	Died after 38 days	−34	Do.

Remarks.—Sciatic nerve of pigeon 339 showed slight degeneration. There were never noticed any definite symptoms of polyneuritis in this bird. Sciatic nerve of pigeons 338 and 340 did not exhibit any degeneration; that of pigeon 341 revealed slight degeneration, although the bird seemed to be in perfect health when it was killed.

EXPERIMENT 4.—"*Patent wheat flour*" *obtained from a Maryland roller mill.*

[Appearance: Pure white; no bran can be detected. P_2O_5 content: 0.25 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
326	Twenty-second day	Died after 43 days	−22	Relieved symptoms on thirtieth day by an extract of rice polishings.
327	Fifteenth day	Died after 67 days	−44	Relieved symptoms on thirtieth and fifty-seventh days by yeast vitamine.
328	.....do	Died after 26 days	−21	Not treated.
329	Tenth day	Died after 16 days	−31	Do.
330	.....do	Died after 12 days	− 7	Do.
331	Twenty-second day	Died after 46 days	−20	Relieved symptoms on twenty-eighth day by an extract of rice polishings.

Remarks.—Pigeon 326 received, on thirtieth day of experiment, 0.5 cubic centimeter of Funk's vitamine fraction from an extract of rice polishings. Bird was greatly improved as a result of this treatment, but gradually developed a relapse several days later. Pigeon 327 received, on thirtieth and fifty-seventh days of experiment, 0.5 cubic centimeter autolyzed yeast vitamine, prepared by means of Lloyd's reagent (dose equivalent to 40 cubic centimeters autolyzed yeast filtrate).

The pigeons of this series all developed polyneuritis within three weeks. The flour was "highly milled" and had a low phosphorus content. The administration of an active preparation of antineuritic vitamine promptly relieved the symptoms.

EXPERIMENT 5.—*"Patent" wheat flour obtained from a roller mill in Virginia.*

[Appearance: Pure white; no particles of bran or germ. P_2O_5 content: 0.20 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
344	Fifteenth day	Died after 29 days	−37	Not treated.
345	Twenty-second day	Died after 30 days	−34	Do.
346	Tenth day	Died after 26 days	−43	Do.
347	Fifteenth day	Died after 39 days	−37	Do.
348	Tenth day	Died after 36 days	−14	Temporary improvement after administration of "vitamine."
349	Fifteenth day	Died after 19 days	−28	Not treated.

Remarks.—All of the pigeons of this lot developed typical polyneuritis between the tenth and twenty-second days after feeding was begun, and died with marked loss in body weight. Pigeon 348 was given one dose of 0.3 cubic centimeter of a fluid antineuritic preparation, obtained from autolyzed brewers' yeast, which caused a temporary improvement in the symptoms.

EXPERIMENT 6.—*"Patent flour" milled in a Michigan roller mill.*

[Appearance: Pure white; contains no bran. P_2O_5 content: 0.206 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
320	Tenth day	Died after 38 days	−27	Not treated.
321	Fifteenth day	do	−13	Do.
322	Eighteenth day	Died after 34 days	−43	Symptoms relieved on the eighteenth day by a preparation made from rice polishings.
323	Fifteenth day	Died after 18 days	−38	Not treated.
324	do	Died after 40 days	−30	Do.
325	do	Died after 83 days	−43	Symptoms relieved on twentieth and thirty-third days by a preparation made from yeast.

Remarks.—Pigeon 322 received 0.5 cubic centimeter of a dilute extract of rice polishings (vitamine fraction), which caused complete disappearance of severe symptoms of paralysis. Pigeon 325 was given, on the twentieth day, 0.5 cubic centimeter of an extract of brewers' yeast (vitamine fraction); severe paralytic symptoms disappeared within 24 hours. On the thirty-third day another attack of polyneuritis was completely relieved by a dose of 1 cubic centimeter autolyzed yeast vitamine, prepared by means of Lloyd's reagent (dose equivalent to 40 cubic centimeters autolyzed yeast filtrate). The pigeon remained free from any symptoms after this treatment for about 25 days.

EXPERIMENT 7.—*"Straight patent flour" milled from winter wheat at a roller mill in South Carolina.*

[Appearance: White; contains a few particles of bran. P_2O_5 content: 0.216 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
351	Twentieth day	Died after 36 days	−27	Not treated.
352	.....do	Died after 38 days	−39	Do.
353	Twenty-sixth day	Killed after 118 days	[1]−34	Relieved symptoms on twenty-sixth day by a preparation made from ox liver; on thirty-fourth day with yeast preparation. Diet changed on Fortieth day.
354	Twentieth day	Died after 52 days	−28	Relieved symptoms on twenty-sixth day by a preparation made from ox liver.
350	Twenty-sixth day	Died after 57 days	−48	Not treated.

[1] Fortieth Day.

Remarks.—Diet of pigeon 353 was changed, on fortieth day of experiment, to a wheat flour obtained from an old-fashioned buhrmill in South Carolina. This change caused the pigeon to regain some of the lost weight (original weight 249 grams, weight at period of dietary change 165 grams; weight at end of experiment, 43 days later, 188 grams). Pigeon was killed after 118 days, being free from symptoms of polyneuritis. Sciatic nerve did not reveal any degenerated fibers.

This experiment, in conjunction with those preceding, shows that a "highly milled" flour with low phosphorus content leads to polyneuritis within about three weeks. The symptoms are due to a deficiency of this food in antineuritic vitamine, as demonstrated by the curative effect of a small quantity of an antineuritic extract from yeast or ox liver.

EXPERIMENT 8.—*"Patent wheat flour" obtained from a Minnesota roller mill through the open market.*

[Appearance: Pure white; no bran can be detected. P_2O_5 content: 0.25 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
1	Twentieth day	25	−39	Died of polyneuritis; sciatic degenerated.
2	Eighteenth day	37	−40	Do.
3	Thirty-first day	38	−33	Severe paralysis relieved with antineuritic material.
4	Twenty-second day	38	−35	Do.
5	Twelfth day	17	−22	Died of polyneuritis; sciatic degenerated.
6	Twenty-eighth day	36	−24	Do.

Remarks.—On this flour the birds developed polyneuritis in about the same time as on highly milled rice. Marked degeneration of the sciatic was found on histological examination. The P_2O_5 content of the flour was low (less than one-third that of "whole wheat").

EXPERIMENT 9.—*"White-wheat bread" obtained from a bakery in Washington, D. C.*

[Appearance: Good; no bran. P_2O_5 content: 0.26 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
37	Forty-second day	45	−36	Polyneuritis cured by extract of "whole-wheat bread."
38	Forty-fifth day	80	−42	Not treated; died of polyneuritis; sciatic degenerated.
39	Fifty-fourth day	64	−23	Severe polyneuritis cured by extract of "whole-wheat bread."
40	Eighteenth day	40	−38	Do.
41	Thirty-first day	35	−41	Not treated; died of polyneuritis; sciatic degenerated.
42	Seventeenth day	40	−39	Do.

Remarks.—The bread used in this experiment was made from a mixture of "patent" and "first clear" flour, yeast, sodium chloride, compound lard, molasses, and evaporated milk. The exact formulas could not be obtained. This bread had a low phosphorus content and led to polyneuritic symptoms in the pigeons of this series in about three to five weeks. It is seen that the incubation period is somewhat longer (three to five weeks) than in birds kept on "patent" flour (2 to 3 weeks). This incubation period is also longer than that observed when polished rice forms the exclusive diet of pigeons. Three of the pigeons were given an extract of the "whole-wheat" bread used in experiment 15. Chart 3 illustrates the gradual loss in body weight on a diet of white bread and the slow recovery after treatment with the extract of "whole-wheat" bread was begun. The addition of yeast and evaporated milk to the flour, in the process of bread making, did not seem to furnish sufficient antineuritic vitamine to prevent polyneuritis.

EXPERIMENT 10.—*White-wheat bread, ordinary baker's bread, purchased on the open market in Washington, D. C., and Spartanburg, S. C.*

[Appearance: White; contained no bran. P_2O_5 content: 0.26 and 0.19 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Died after—	Change in body weight in per cent of original weight.
		Days.	
116	Thirty-second day	32	Not determined.
120	Twentieth day	21	Do.
300	Twenty-fifth day	42	−15.
304	Twenty-first day	29	−29.
305	Twenty-fourth day	43	−4.
307	Twenty-fifth day	46	−18.
401	Fourteenth day	15	Not determined.
402	Fortieth day	40	Do.

Remarks.—From these experiments it would seem that the incubation period of polyneuritis is somewhat prolonged (about 14 days) as a result of the addition of yeast and evaporated milk to the highly milled flour in the process of bread making. Both yeast and milk are known to contain antineuritic vitamine.

EXPERIMENT 11.—*High grade "patent" wheat flour + Lloyd's reagent (inactive). This flour was obtained from a Minnesota roller mill and 1 per cent of Lloyd's reagent incorporated with it.*

[Appearance: White; no coarse particles. P_2O_5 content: 0.25 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
13	Thirty-first day	38	−43	Experiment discontinued after 38 days.
14	Thirty-eighth day	38	−27	Do.
15	Twenty-fifth day	38	−40	Died of polyneuritis; sciatic nerve degenerated.
16	Thirty-first day	38	−38	Experiment discontinued after 38 days.
17	.....do	38	−32	Do.
18	.....do	54	−48	On fifty-fourth day pigeon was dying; killed with chloroform; sciatic degenerated.

Remarks.—This experiment shows that "patent" flour, with the addition of Lloyd's reagent (fuller's earth) which has not been activated by autolyzed yeast, does not prevent the appearance of polyneuritis in pigeons. These results are in marked contrast with experiments illustrated by chart 5.

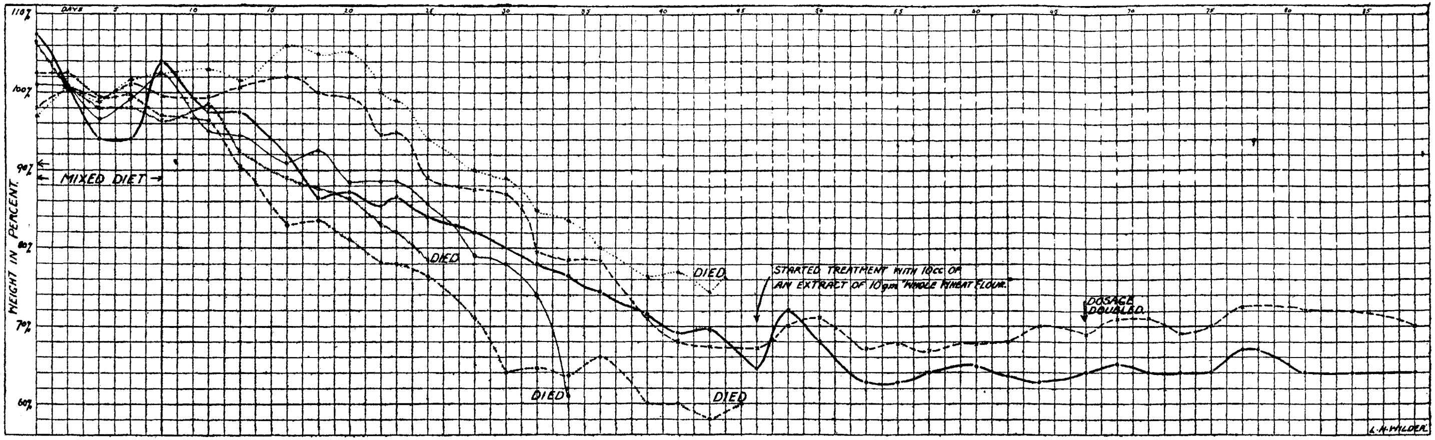

CHART 1.—Experiment 12. Weight curve of pigeons on "highly milled" (patent) wheat flour. All of the pigeons of this group developed polyneuritis within 21 days and lost considerable body weight. Four of the birds died after having been on this diet 17, 26, 36, and 37 days, respectively. The two remaining birds received an extract of "whole wheat" flour and were cured of their paralytic symptoms, but did not recover their lost body weight during the next 40 days.

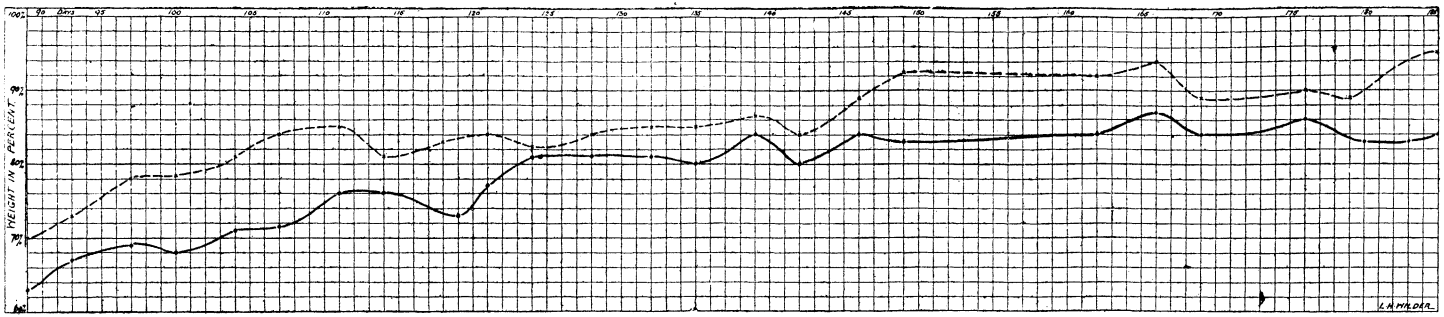

Chart 2 (Continuation of Chart 1).—Experiment 12. Recovery of body weight of pigeons on diet of "highly milled" (patent) wheat flour, as a result of the addition to the flour of 1 per cent activated Lloyd's reagent. The previous administration of an extract of "whole wheat" flour had cured the pigeons of the paralytic symptoms, but had not led to a recovery of body weight. The amount of extract was probably not sufficient for this purpose.

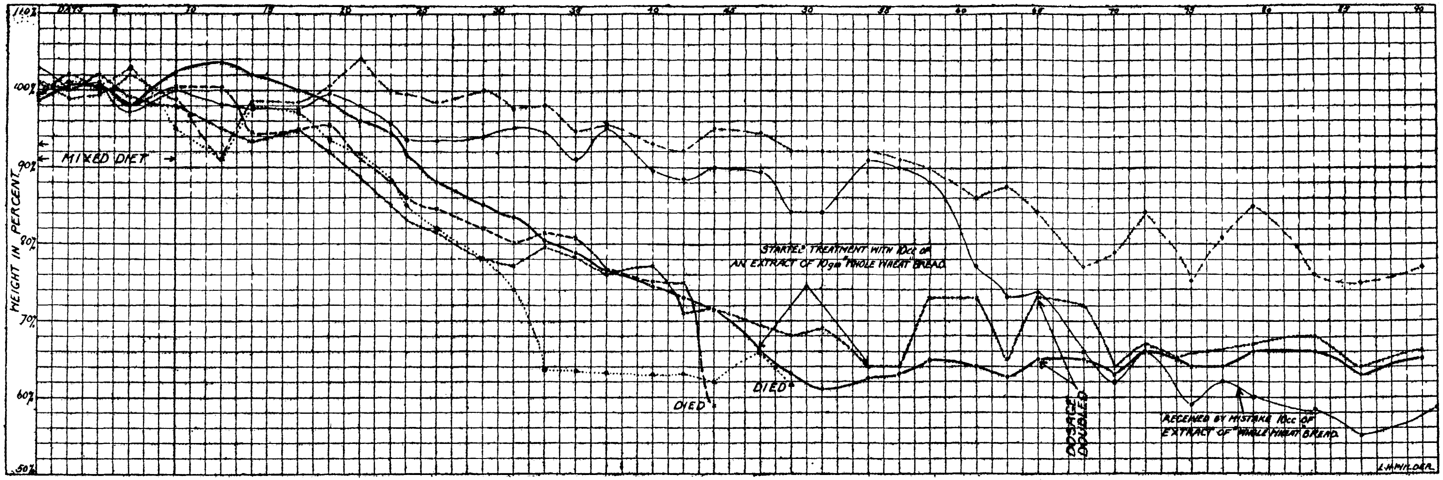

CHART 3.—Experiment 13. Weight curve of pigeons on diet of "white" bread. Symptoms of polyneuritis appeared a little later than on a diet of "highly milled" flour (see Chart 1). Two of the animals died of polyneuritis; the others were treated with an extract of "whole wheat" bread and were cured of their symptoms. Later on (Chart 4) the surviving pigeons received daily 50 mg. of activated Lloyd's reagent (containing antineuritic vitamine) by stomach.

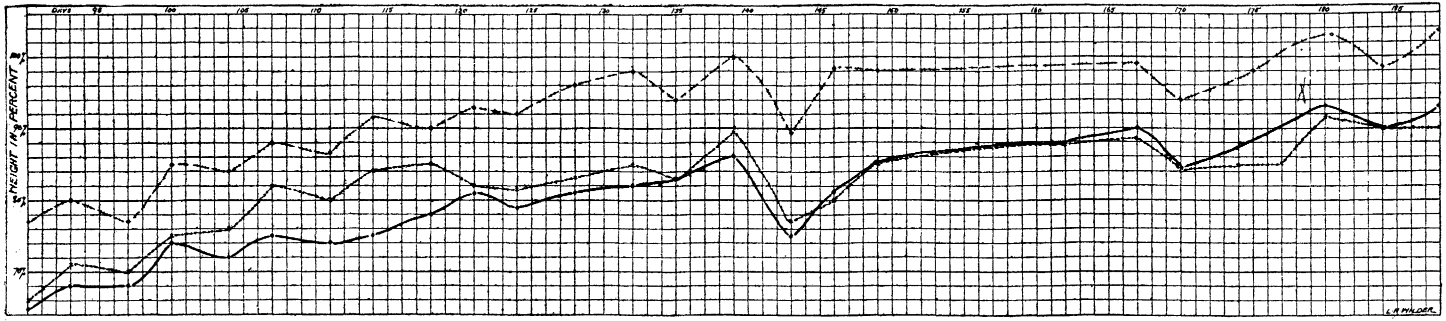

CHART 4 (Continuation of Chart 3).—Recovery of pigeons on diet of "white bread" as a result of the daily administration of 50 mg. of activated Lloyd's reagent.

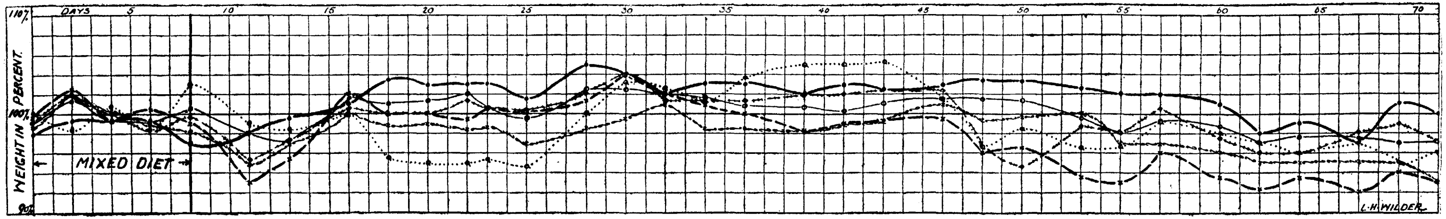

CHART 5.—Experiment 14. Weight curve of pigeons on diet of "highly milled" (patent) wheat flour+0.5 per cent activated Lloyd's reagent, showing prevention of loss of body weight in pigeons on this mixture. In another experiment, the same amount of *inactive* Lloyd's reagent was added to the patent flour. The pigeons developed polyneuritis within three weeks and lost about 30 per cent of body weight, thus showing that fullers' earth per se can not prevent polyneuritis.

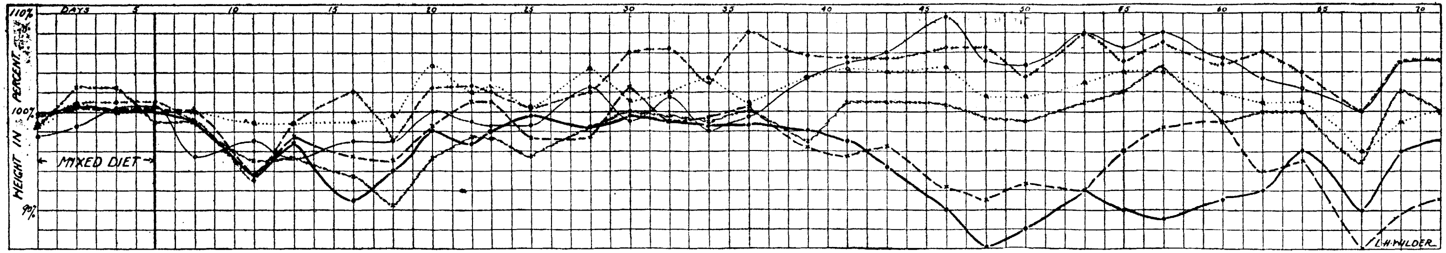

CHART 6.—Experiment 15. Weight curve of pigeons on diet of "whole wheat" bread, showing that "whole wheat" bread contains sufficient antineuritic vitamine to prevent a loss in body weight of pigeons fed exclusively on this diet. The birds of this series did not develop any symptoms of polyneuritis.

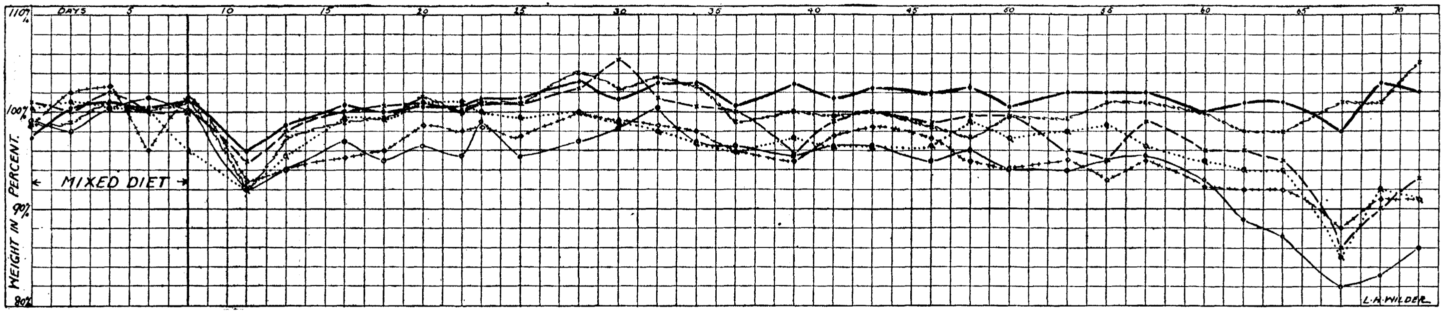

CHART 7.—Experiment 16. Weight of pigeons on diet of "whole wheat" flour. This chart shows that the pigeons fed on "whole wheat" flour alone do not lose weight. This food is adequate as the sole source of antineuritic vitamine. No symptoms of polyneuritis were observed in any of these birds.

Experiment 17.—*Whole corn.*

[P_2O_5 content: 0.76 per cent.]

No of chicken.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.
		Days.	
6	No symptoms	222	−14
10	.....do	428	− 5
11	.....do	188	− 2

Remarks.—The animals of this group were healthy, full-grown chickens. They were kept in individual small cages throughout the period of observation. The lack of cage space may account for the trivial loss in body weight, as it is very difficult to keep fowls in perfect condition in such narrow confinement for so long a time.

Experiment 18.—*"Old process water-ground corn meal" obtained from an old-fashioned buhr mill in Georgia.*

[Appearance: Contains large particles of bran and germ. P_2O_5 content: 0.659 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
66	No symptoms	150	−30	Not treated.
67	.....do	73	−36	Do.

Remarks.—Pigeons 66 and 67 remained perfectly well, but lost considerable weight. This loss of weight was due to the underfeeding of these birds. They received only 10 grams corn meal daily, instead of 15 to 20 grams. In spite of the loss of weight, these animals did not exhibit the slightest signs of polyneuritis during the long period of observation.

Experiment 19.—*Corn grits (hominy) obtained from an old-fashioned buhrstone mill in South Carolina.*

[Appearance: Practically all the bran and germ mixed with the finer endosperm. P_2O_5 content: 0.668 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
98	No symptoms	152	−11	Not treated.
99	No symptoms; escaped	98	(1)	Do.
96	No symptoms	77	+9	Do.

[1] Not determined.

EXPERIMENT 19a.—*Same as used in experiment 19, except that the larger particles of bran were removed by passing through a coarsely meshed sieve.*

[P_2O_5 content: 0.59 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
102	No symptoms	152	−8	Not treated.
103	.....do	152	−6	Do.
100	.....do	152	−10	Do.

EXPERIMENT 20.—*Corn meal used at Milledgeville State Hospital, Milledgeville, Ga.*

[Appearance: Contains considerable bran and germ. P_2O_5 content: 0.677 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
72	No symptoms	52	−38	Not treated.
73	.....do	84	−15	Do.

Remarks.—Both pigeons were underfed, receiving only 10 grams of cornmeal daily. This fact accounts for the loss of body weight.

Pigeon 73 also received old process corn meal, obtained from the United States Penitentiary, Atlanta, Ga. (0.77 per cent P_2O_5). This bird remained well and apparently in perfect health for a period of 84 days when the experiment was discontinued. No symptoms of polyneuritis were exhibited.

EXPERIMENT 21.—*Corn grits obtained from State institutions in Alabama and Georgia.*

[Appearance: Highly milled. P_2O_5 content: 0.169 and 0.201 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
61	Twenty-second day	41 days	[1] −22	Beginning with twenty-second day, daily dose 0.2 c. c. yeast extract.
62	Twentieth day	45 days	(2)	Beginning with twentieth day, daily dose 0.2 c. c. yeast extract.
64	Eighteenth day	Died after 34 days	−48	Not treated.
411	.....do	Died after 31 days	−33	Do.

[1] Twenty-second day of experiment. [2] Not determined.

Remarks.—Pigeons 61 and 62 received grits which was used in the State hospital in Alabama (P_2O_5 content=0.169 per cent). Pigeon 64 received grits used in a hospital for the insane in Georgia (P_2O_5 content=0.201 per cent). All of these products contained very little bran and germ and were products of roller mills. Pigeons 61 and 62 responded very well to the treatment with yeast extract (disappearance of polyneuritic symptoms) and were in excellent condition at the end of the period of observation.

Experiment 22.—*"Highly milled" corn grits obtained from a roller mill in North Carolina.*

[Appearance: Contains a trace of bran and germ. P_2O_5 content: 0.21 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
91	Thirty-first day.........	Died after 72 days.......	Not determined...	Symptoms relieved on sixty-fourth day by yeast extract.
92	Twenty-third day.......	Died after 92 days.......	.....do.............	Improved on sixty-seventh day by alcoholic extract of yeast.
93	Thirty-first day.........	Died after 91 days.......	.....do.............	Improved on seventy-third day by yeast extract.
94	Forty-seventh day......	Died after 95 days.......	.....do.............	Marked improvement on sixty-fifth day by 0.2 gm. alcoholic yeast extract.
97	Thirty-first day.........	Died after 64 days.......	.....do.............	Not treated.

Experiment 23.—*Highly milled corn grits and wheat bran. The grits were obtained from a roller mill in North Carolina and the bran from an old-process (stone) mill in South Carolina. The grits were the same as used in Experiment 22.*

[P_2O_5 content of corn grits: 0.21 per cent. P_2O_5 content of wheat bran: 2.48 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Diet.
87	No symptoms....................	149 days.................	0	35 gm. corn grits+10 gm. wheat bran.
85	.....do..........................	.....do...................	+ 3	
86	.....do..........................	.....do...................	− 9	
88	Sixty-seventh day...............	Died after 68 days.......	(1)	40 gm. corn grits+5 gm. wheat bran.
89	One hundred and forty-ninth day	226 days..................	+ 8	
90	One hundred and fiftieth day...	Died after 158 days......	−31	

[1] Not determined.

Remarks.—Pigeons 85, 86, and 87 remained in perfect condition throughout the period of observation. Pigeons 88, 89, and 90 developed polyneuritic symptoms after a considerable length of time and two of the birds died of the disease. Pigeon 89, however, recovered from the paralytic attack, regained its lost body weight and appeared perfectly well at the end of the period of observation (226 days).

Experiment 24.—*Highly milled corn grits with addition of corn bran. The grits were the same as used in experiment 22, and the bran was obtained from old-process corn meal by passing the latter through a wide-meshed sieve.*

[P_2O_5 content of corn grits: 0.21 per cent. P_2O_5 content of corn bran: 0.787 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
81	Seventy-third day......	Died after 113 days......	Not determined...	Symptoms relieved on seventy-third day by 10 c. c. of dilute yeast extract.
101	.....do..................	Died after 115 days......	.....do............	Do.

Remarks.—Both pigeons of this lot received a mixture of 15 grams of corn grits and 5 grams of corn bran. The addition of corn bran caused a very considerable delay in the onset of polyneuritis (about 40 days). This furthermore seems to indicate that corn bran is probably not as rich in antineuritic substance as either wheat bran or possibly corn germ. On examination of the corn bran it was noticed that very little of the so-called aleuron layer adhered to the cellulose layer of the bran.

Both pigeons recovered temporarily from their paralytic symptoms as a result of a single dose of an antineuritic yeast preparation. The birds again recovered their lost appetite and remained free from symptoms for 38 days (pigeon 81) and 41 days (pigeon 101), respectively.

In order to discover whether a larger addition of corn bran would offer complete protection from polyneuritis, pigeon 74 was fed on a mixture of 10 grams highly milled corn grits (0.20 per cent P_2O_5) and 10 grams corn bran (0.78 per cent P_2O_5). The corn grits used were the same as fed to pigeon 411 (experiment 21) and had caused symptoms of polyneuritis on the eighteenth day after feeding was begun. Pigeon 74 remained well on this diet for two months, when the experiment was discontinued.

Experiment 25.—*Corn germ obtained from a roller mill in Indiana.*

[P_2O_5 content: 2.81 per cent.]

No. of pigeon.	First appearance of polyneuritis.	Period of observation.	Change in body weight in per cent of original weight.	Notes.
		Days.		
70	No symptoms	85	−17	Not treated.
71	....do	92	−20	Do.

Remarks.—These pigeons were underfed (see p. 649), receiving only 10 grams of food daily. They never exhibited the slightest symptoms of polyneuritis and were lively throughout the period of observation.

Conclusions.—(1) The results obtained in this investigation clearly show that for pigeons an exclusive diet of whole wheat or corn furnishes an adequate supply of antineuritic vitamine.

(2) The antineuritic vitamine seems to reside in the peripheral layers and the germ of these seeds, whereas the endosperm is relatively poor in this substance.

(3) If wheat and corn foods containing only a small percentage of the peripheral layers and germ of the seed are fed to pigeons and chickens exclusive of other food, polyneuritic symptoms appear on an average of three weeks after the beginning of the feeding period. The appearance of polyneuritis is preceded by a gradual loss in body weight. The birds can be relieved of their paralysis in a striking way by the oral or subcutaneous administration of a highly concentrated preparation of antineuritic vitamine derived from "whole-wheat" bread, yeast, ox liver, rice polishings, or beans.

(4) The addition of yeast (in amounts used by bakers) in the preparation of bread from highly milled flour does not prevent the appearance of polyneuritis in birds fed on this food, but prolongs slightly the period of incubation.

(5) The addition to "highly milled" flour, or bread made from "highly milled" flour, of a small amount of antineuritic vitamine preparation will correct this particular dietary deficiency, and will prevent the appearance of polyneuritis and the loss of body weight.

(6) The total phosphorus content of corn and wheat foods is a fairly satisfactory index of the amount of antineuritic vitamine contained in these foods. In a general way, it can be said that a high total phosphorus content is an indication that the particular corn or wheat product is relatively rich in antineuritic vitamine.

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